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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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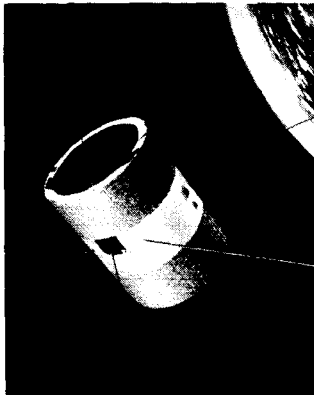
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March 31, 1967**

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PROJECT: ATS-A

(To be launched no
earlier than April 4)

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SECOND ATS,
G-STABILIZED,
READY TO GO

A record size, 252-foot long satellite (including 123 foot booms extending from opposite sides) is scheduled for launch from Cape Kennedy, Fla., no earlier than Tuesday, April 4.

The National Aeronautics and Space Administration will launch this second in a series of five Applications Technology Satellites, ATS-A (ATS-II in orbit), on board an Atlas-Agena launch vehicle into a 6,900-mile circular orbit. It will be inclined 29 degrees to the Equator.

Primary mission objective is to test and evaluate a passive gravity gradient control system which uses the force of gravity to keep the spacecraft stabilized on three axes and pointed toward Earth.

The 815-pound ATS-A will be the first satellite with sufficient instrumentation to verify the design and mathematical model of a three-axis gravity gradient control system in conjunction with a detailed computer program.

-more-

The Earth's gravity gradient is the reason one side of the Moon always presents the same face toward Earth. Billions of years ago the Moon became Earth's first gravity gradient stabilized satellite.

In addition to the gravity gradient experiment, ATS-A will carry communications (voice, television and teletype), meteorological (cameras) and several scientific experiments to measure the orbital environment of the satellite.

The ATS program is designed to investigate technology common to a number of spacecraft applications through flight experiments carried on spin-stabilized and gravity gradient stabilized spacecraft. It is intended to improve spacecraft technology, develop long-life control systems, advance spacecraft communications and improve long range weather predictions.

Before the end of 1969, there will be four spacecraft of the ATS type in synchronous orbit at 22,300 miles and one, ATS-A, in the 6,900-mile orbit. ATS-C will be spin stabilized while D and E will be gravity gradient stabilized. ATS-B, launched last Dec. 6, is operating successfully as ATS-I.

ATS-A will carry two standard television cameras (525 lines) as a part of the gravity gradient experiment. These cameras will provide the first measurements of the bending effects due to solar heating and radiative cooling on the booms extending out from the satellite.

It is predicted they will bend three to four feet, but confirmation or disproof of the prediction is important to our knowledge of how the booms behave in space.

The degree of bending will affect the accuracy with which the satellite can point toward the Earth, hence, its compatibility with communications and meteorological experiments requiring accurate Earth pointing.

The amount of boom bending at the ATS-A altitude will be compared with later synchronous orbit flights. As a result of these flights, engineers will have precise information on the performance of gravity gradient booms needed for stabilization.

In addition, engineers will be able to view the satellite's attitude in space, using the Earth as a reference point, plus the full Earth disk "live" on television monitors.

Other tests slated for ATS-A include a microwave communications experiment, two meteorological cameras, environmental measurements experiment (scientific) and a Department of Defense albedo experiment.

Basic objective of the microwave communications experiment is to transmit simultaneously voice, television (color or black and white), telegraph and digital data to several ground stations.

The meteorological package consists of two advanced vidicon cameras. One camera will have a wide angle lens (50 degrees) and will provide a picture of the entire Earth's disk with a 10-mile resolution. The narrow angle (3 degrees) camera will have a $\frac{1}{2}$ -mile resolution (about the same as the Nimbus II weather satellite).

Meteorological pictures never have been taken from a gravity gradient satellite. Officials want to learn if camera shutter and tape recorder motion have any great effect on the ATS-A control system.

The environmental measurements package consists of eight separate experiments to measure radiation damage, thermal effects, erosion and energy particle type, density, energy, and directivity and magnetic fields.

m ATS-I now is in synchronous orbit above the equator near Christmas Island in the Pacific (151 degrees West Longitude). Performance of the satellite has been excellent.

The Very High Frequency (VHF) experiment has performed exceptionally well. In several tests officials have been able for the first time to conduct two-way voice communications between NASA's Goddard Space Flight Center, Greenbelt, Md., and commercial aircraft in the air and on the surface as far away as Tahiti Island in the Pacific.

The Spin Scan Camera System (SSCS) continues to photograph about 40 per cent of the world's weather. In synchronous orbit the camera can photograph the birth and death of storms which previously was not possible.

The ATS program is directed by NASA's Office of Space Science and Applications. Project management is under the direction of the Goddard Center.

NASA's Lewis Research Center, Cleveland, is responsible for the Atlas-Agena launch vehicle. Launch operations are directed by Kennedy Space Center, Fla.

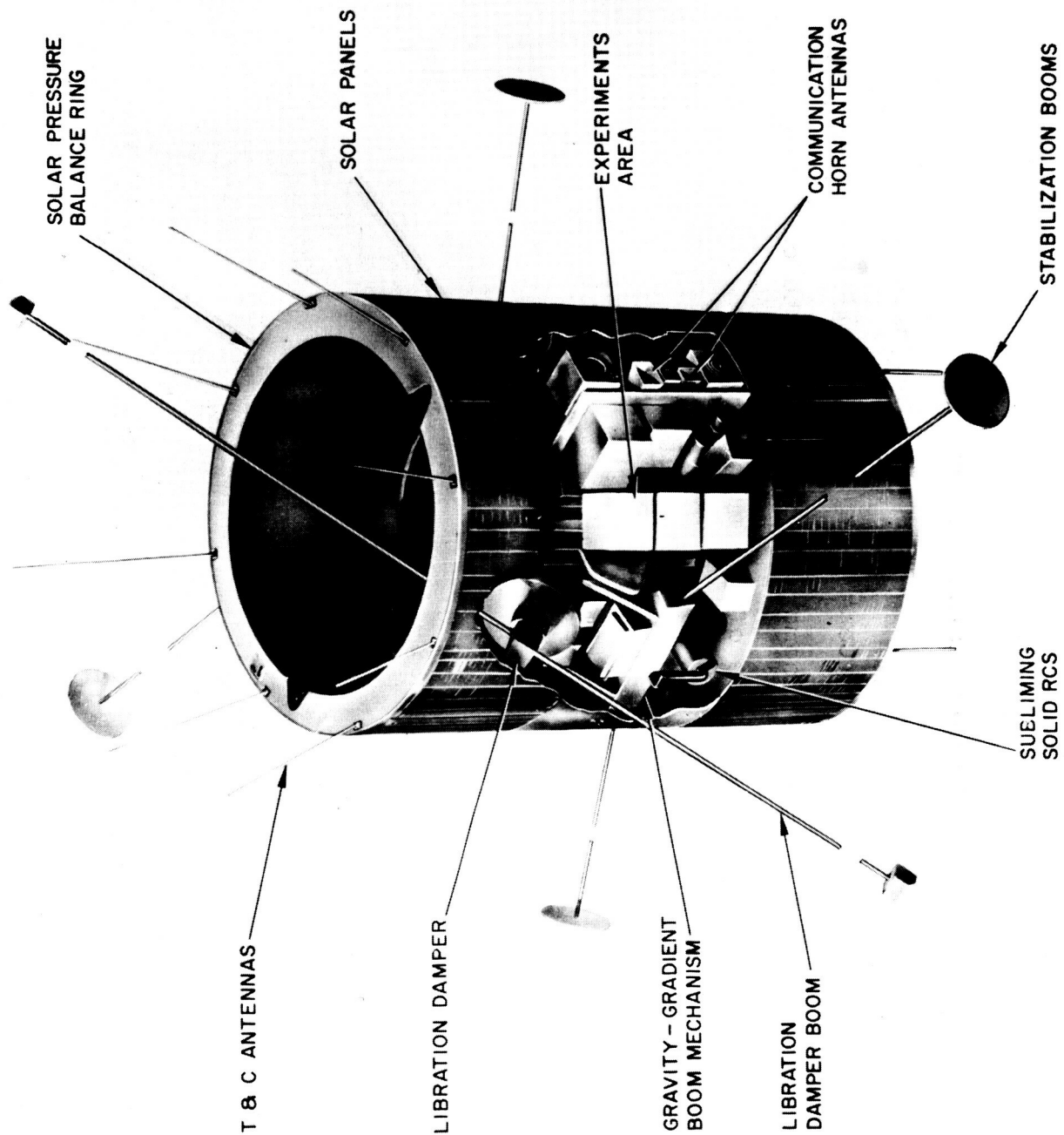
Hughes Aircraft Co., Space Systems Division, El Segundo, Cal., is responsible for spacecraft design, development and fabrication as well as integration of spacecraft experiments.

General Electric Co., Missiles and Space Division, Valley Forge, Pa., made the gravity gradient attitude and control system.

General Dynamics/Astronautics, San Diego, Cal., developed the Atlas rocket and Lockheed Missile and Space Corp., Sunnyvale, Cal., the Agena stage.

(END OF GENERAL RELEASE;

BACKGROUND INFORMATION FOLLOWS)



ATS-A GRAVITY GRADIENT SPACECRAFT

GRAVITY GRADIENT STABILIZATION EXPERIMENT

The advantages and scientific basis of gravity gradient stabilization are that:

1. A long object in space will tend to align itself with the vertical because the Earth's gravitational attraction decreases with distance from Earth, hence the end of a long object nearest Earth will effectively "weigh" more than the one farthest away.
2. Since such an alignment is passive -- take place without expenditure of energy or fuel -- it offers a potential for a major increase in the lifetimes of oriented spacecraft.
3. The ATS-A experiment will give definitive information about the performance of gravity gradient orientation systems at higher altitudes (gravity gradient strength decreases rapidly with distance from Earth) which are useful for many space applications.
4. The type of information obtained from ATS-A will be sufficiently detailed to aid in designing future gravity orientation systems.

In orbit, ATS-A will have a tendency to swing away from the local vertical due to a combination of the Earth's magnetic field, solar pressure, and movements of tape recorders and camera systems. However, an onboard damper system is expected to stabilize the spacecraft in all three axes within three degrees.

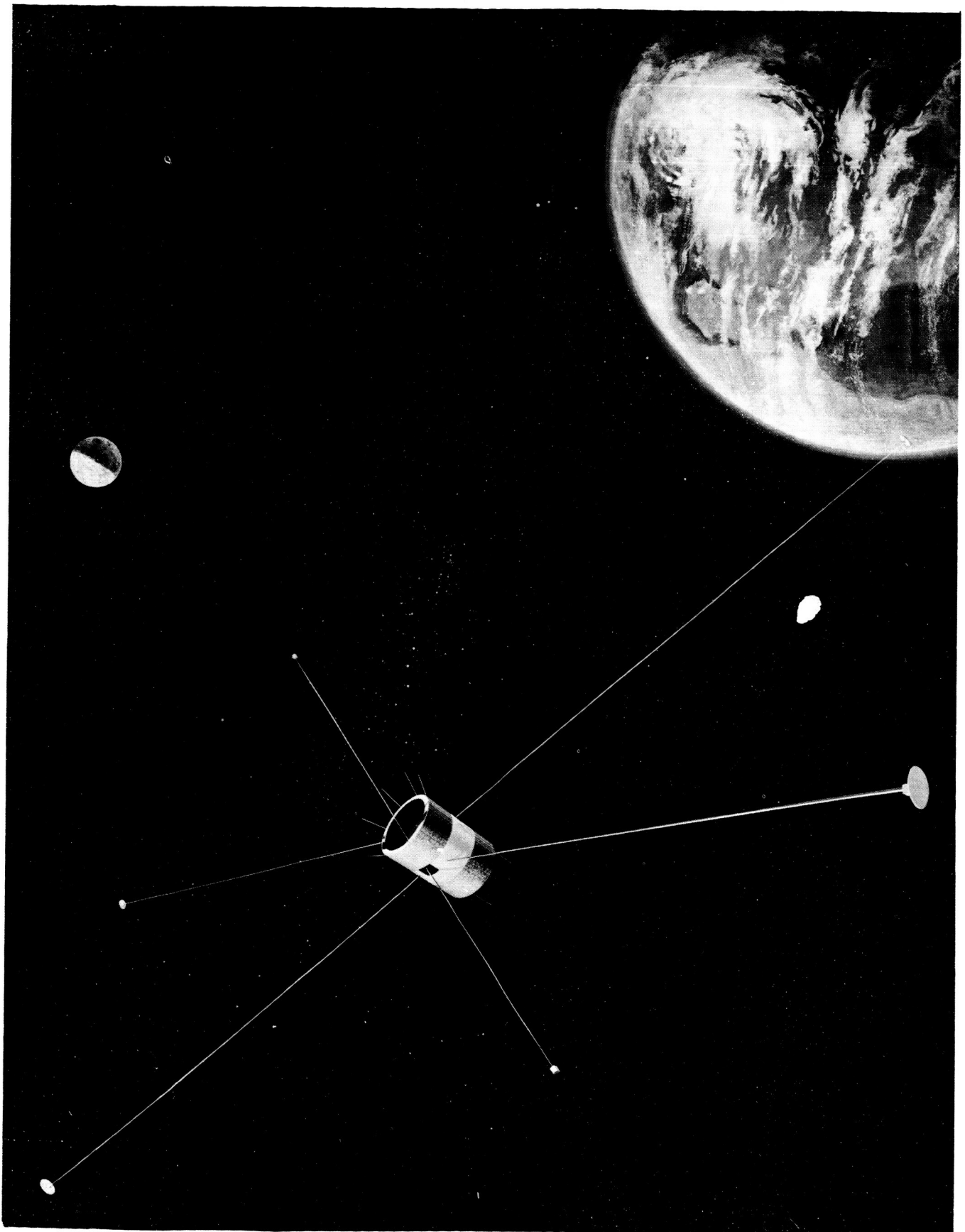
Because gravity gradient stabilization systems are passive they have a high degree of reliability and a life expectancy greater than five years.

They require no power, once deployed, and are lighter than active systems because there are no electronics, no stored gas and no sensors.

Hardware

The ATS-A gravity gradient control system consists of a Primary Boom Subsystem; Damper Boom Subsystem; Combination Passive Damper (CPD); Television Cameras; Attitude Sensor Subsystem; Power Control Unit (PCU).

-more-



ARTIST CONCEPT OF ATS-A SPACECRAFT

Primary Boom Subsystem

When fully extended, the four 123-foot booms for a giant X configuration. The basic ATS-A spacecraft (5-foot diameter) is at the apex of the X.

The booms are made of two-mil beryllium copper strips two inches wide.

Each boom weighs about two pounds. They have been formed from a heat treated flat strip into a tubular shape and then flattened under stress and wound onto power-driven drums.

The beryllium copper is silver plated to minimize the boom bending from the Sun.

Two and one-half pound tip weights are fixed about four inches from the end of each boom to increase the spacecraft's inertia and improve its stability.

Attached to the end of each boom are circular 9-inch diameter plastic targets made of LEXAN material.

The gravity gradient cameras will be able to view these targets to gather information on boom extension and retraction, and to help measure the amount of bending from thermal effects.

During powered flight, the booms will be stored inside the spacecraft as flat tapes on motor driven drums. Shortly after spacecraft separation they will simultaneously uncoil into cylindrical tubes $\frac{1}{2}$ -inch in diameter.

The booms uncoil at the rate of one foot per second. It will take slightly more than two minutes for the primary booms to fully extend.

Two electric motors are used for controlling the booms. One motor is used for extending and retracting the rods, and the other for scissoring (opening and closing the X-shaped booms like a scissors).

These booms can be scissored from 11 to 31 degrees off the local vertical. NASA engineers predict that 25 degrees is ideal for stability purposes. By scissoring, engineers will be able to measure performance against predictions and correct the mathematical model if required.

Damper Boom Subsystem

ATS-A will be stabilized in pitch, yaw and roll axes using a single-axis damper. A single-axis damper saves weight and is simple and reliable. To achieve this, the damping axis is positioned between the pitch and roll axes and does not lie along a principal axis of the primary body.

The damper, also made of beryllium copper, consists of two 45-foot booms which extend from the damper axis of nutation in opposite directions, in a plane normal to the damper axis.

The damping boom will always move in the opposite direction the spacecraft is trying to move. Its purpose is to eliminate or dissipate unwanted spacecraft motion.

The damper booms take 22 seconds to deploy fully. Unlike the primary booms, they are not extended by a motor.

The booms are released by a squib-activated thruster mounted on the damper. This releases a ball-lock device which cages the two storage spool housings during powered flight. Lift-off springs initiate the motion of the tip assemblies. Then, the elastically wound tape begins to erect itself and continues to propel the tip assembly to the full length of the booms.

The damper booms, unlike the primary booms, cannot be retracted once deployed. There is no need to do so with the ATS-A orbital test plan.

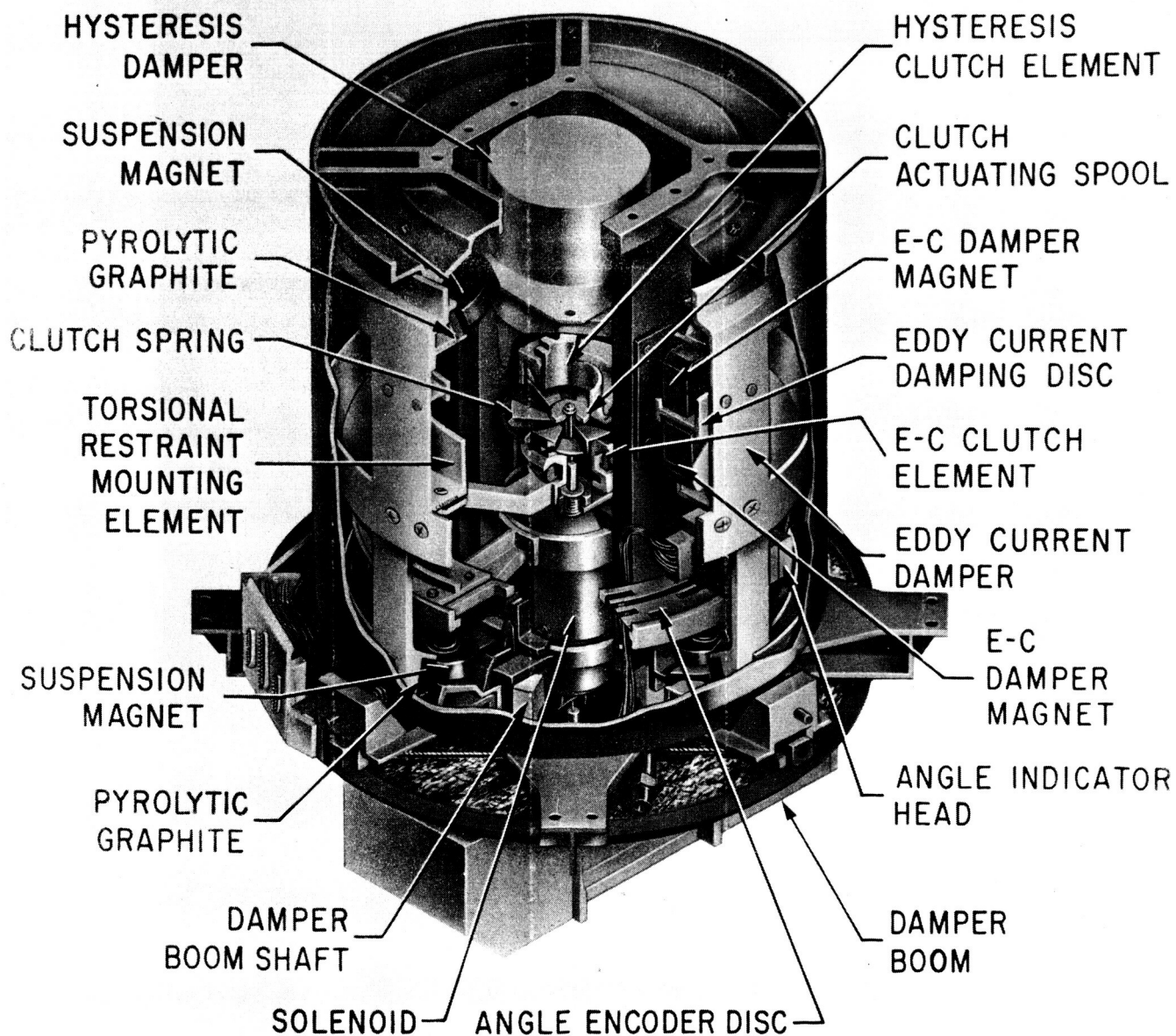
Combination Passive Damper

Because of its research and development role, ATS-A will carry two damping systems to enable engineers to determine which is the better. The entire combination passive damper weighs 24 pounds. An operational satellite would use only one damping system and this would weigh five pounds.

One of the systems is called Eddy Current Damper (ECD) and the other is a Hysteresis Damper. Either of the two units can be clutched to the damper boom which forces it to move and, therefore, damp out motion which affects the satellite's stability.

The eight-inch diameter ECD is diamagnetically suspended (floats unattached) by doughnut shaped pyrolytic graphite (just like the lead in a pencil) and 16 magnets.

COMBINATION PASSIVE DAMPER



Torsional restraint for the ECD is provided by a crescent-shaped paramagnetic material acted upon by permanent magnets. The wider portion of the thin crescent has a greater attraction for magnets producing the torque that returns the rotor to null position (when the damper boom is parallel to the Earth's curvature) which is the widest portion of the crescent.

Eddy current damping is provided by an aluminum disk and permanent magnets, using the principle that when a conductor is moved through a magnetic field eddy currents are produced that resist motion and, thus, dissipate energy.

The ATS-A mission will be the first flight test for the Hysteresis Damper which is shaped like, and is about the same size, as a beer can.

Inside the can-shaped damper, a $1\frac{1}{2}$ -inch diameter disk is suspended on a thin wire about the size of a human hair. Eight small magnets are suspended around the disk. As the disk moves through the magnetic field, the dipoles flip, or reverse themselves, from North-South to South-North etc. The wire, which is attached to the disk, has a null point and acts like a spring to restore the damper boom to its null position.

It is similar to attaching a very small weight to the end of a string which has been tightly wound. When the weight is released, the spring spins, eventually returning to its original position.

Switching from one damper to the other while in orbit is accomplished by an electrical solenoid which actuates a washer-type clutch diaphragm made of beryllium copper.

The diaphragm action is of the flip-flop type with the solenoid just pushing the diaphragm over the center to actuate it. The positioning and stroke of the solenoid and diaphragm are such that the actuator does not touch the diaphragm during damping operation.

Attitude Sensor System

This subsystem consists of several types of sensors which can be used independently, or in combination, to determine the position of the satellite with respect to the local vertical within one degree.

The ATS-A attitude sensors include a solar aspect sensor system, two infrared Earth sensors, a polarized antenna (supplementary) and two commercial (525 lines) television cameras.

The Solar Aspect Sensor, capable of angle determination to within one degree, is a digital system composed of a single electronics unit and five solar detector assemblies. The detectors are positioned on the top, bottom and sides of the ATS-A spacecraft.

Each of the solar detectors has a 128- by 128-degree rectangular field of view. The detector is comprised of two gray coded reticles, solar cells, and the housing.

The two infrared Earth sensors are of the scanner type consisting of a small circular mirror suspended on flexure pivots which are driven by pulsed electrical coils.

The mirror causes the field of view of a germanium telescope to scan back and forth in space with a total sweep which covers the Earth from edge to edge.

A semiconductor bolometer generates an Earth pulse which is reconstructed by a Schmitt trigger, which triggers on the Infrared Radiance signal from the Earth.

The polarized communications antenna of the spacecraft will measure the polarization angle of the incoming RF energy from the spacecraft linearly-polarized, wide-band communications antenna.

The accuracy of measurement of the incoming RF energy is affected by the Earth's ionosphere. However, it is possible to eliminate this source of error.

Gravity Gradient Television Cameras

ATS-A will be the first U.S. satellite to carry commercially compatible cameras which can project a picture on standard home TV sets.

Weighing a total of seven pounds, the cameras will be positioned at the top and bottom of the spacecraft at the center of each V formed by the X-shaped, primary booms.

The two standard (525 lines) television cameras, which have a relatively short life of about 3,000 hours, are being carried on ATS-A to measure the thermal bending characteristics of the gravity gradient booms as well as to verify the satellite's sensory data.

Fastened to the ends of the four, X-shaped booms, are 9-inch diameter shiny tip targets to enhance the motion picture coverage.

A wide angle lens with a focal length of 10 mm is used. This results in an angular field of 65 degrees in the horizontal plane and 49 degrees in the vertical plane.

The frame rate is 30 cycles per second.

Power Control Unit

The overall gravity gradient stabilization system is tied together electrically by a single Power Control Unit (PCU). The PCU incorporates all power, command and telemetry interfaces between the spacecraft and the gravity gradient system. It also contains the necessary spacecraft interface equipment for all gravity gradient system diagnostic measurement. When commanded from the ground, the PCU will provide power to the various attitude sensing and control devices associated with the gravity gradient stabilization system.

Orbital Maneuvers

The X-shaped ATS-A configuration is ideal for operating experiments and conducting one of the key ATS-A experiments -- varying the length and angle of the long gravity gradient rods.

NASA engineers want to determine how much the rods can be shortened and scissored without affecting, to any great extent, the satellite's stability.

The scissoring of gravity gradient rods never has been attempted on a U.S. satellite.

During these maneuvers, ATS-A will perform several turn-around (in slow motion) maneuvers. It will roll, pitch and yaw, and in some cases completely flip over -- a complete flip-over will take about three hours.

When the rods are shortened, ATS-A will increase its spin and vice versa similar to the way a figure skater spins with folded arms and slows down by extending the arms.

The operations plan calls for the gravity gradient rods to begin extending shortly after the spacecraft separates from the Agena (about two hours after lift-off) over the Indian Ocean 2,000 miles West of Australia.

Initial stabilization should be within about 45 degrees of local vertical. Approximately three days will be required to stabilize ATS-A in all three axes.

It is possible that the spacecraft might be inverted during initial stabilization. If so, the spacecraft can be turned over by extending or retracting the long booms, or by firing small micro-pound subliming rockets. (see page 19)

The two small subliming rockets produce a thrust of 600 micro-pounds (millionths of a pound), which is equivalent to the weight of a small sewing needle.

COMMUNICATIONS EXPERIMENT

This system is identical to the experiment carried on ATS-I. The experiment will be conducted with two microwave repeaters (receiver/transmitter) which make up the spacecraft's super high frequency (SHF) communications subsystem.

Both repeaters operate in three modes: the first two, (1) multiple-access and (2) frequency translation, are used in the microwave communications tests. The third mode, (3) wideband data, is used for transmitting television pictures from the spacecraft's two meteorological cameras to the ground.

Multiple Access Mode Tests

The basic objective of operating the microwave repeaters in this mode is to evaluate the Single Side Band (SSB) technique for multiple-access communications under high doppler rates inherent in medium altitude orbits. This experiment will be compared to the data obtained from ATS-I.

The experiment affords a maximum number of voice channels in the minimum bandwidth of the overcrowded radio frequencies.

In the multiple-access mode, the two microwave repeaters serve as telephone relays by permitting the simultaneous two-way interconnection of many ground stations.

Use of both repeaters will provide a total of 1,200 one-way or 600 two-way voice circuits when properly equipped ground stations are used.

During the multiple-station access tests, transmissions from all of the participating ground stations are collected at the spacecraft as a composite SSB signal in the 6,000 MC frequency range.

This composite signal is converted to a Phase Modulated (PM) signal in the 4,000 MC range by the repeater before re-transmission to the receiving ground terminals.

The SSB/PM conversion technique is employed for the multiple access tests because PM provides a constant power signal which can be amplified in an efficient manner while utilizing a minimum of weight, space and the spacecraft's onboard power. This could not be accomplished if SSB were used for the ept communications loop.

Since SSB signals are particularly sensitive power frequencies and power levels, precautions have been taken insure that these two factors remain as constant as possible.

Frequency Translation Mode Tests

The two microwave transponders are operated in this mode to evaluate a high quality Frequency Modulation (FM) system for relaying wideband data such as color television, telegraph, digital and facsimile data.

The FM system used for these tests is a refinement of the systems used on the Relay, Telstar and Syncom communications satellites.

In the Frequency Translation Mode, FM signals are received from a ground station in the 6,000 MC frequency range and translated to FM signals in the 4,000 MC range before re-transmission to the ground. During the translation, the signals are amplified.

The primary design criteria for the Frequency Modulation system includes meeting the specifications for color television. Wideband circuitry is utilized throughout the signal chain of the system so that the resulting usable band is 25 MC.

This meets all International Radio Consultative Committee (IRCC) recommended television standards when utilized with ground stations appropriately equipped.

Since wide band data transmissions cover a relatively wide range of frequencies, two-way simultaneous transmissions of such data will require the use of both microwave repeaters.

In such a case, one ground station will use one complete channel for transmission one way while the cooperating station will monopolize the other microwave channel.

METEOROLOGICAL EXPERIMENT

ATS-A will be the first U.S. gravity gradient satellite to carry meteorological cameras.

Objectives are to evaluate the effect that camera shutter and tape recorder movements have on the satellite's pointing accuracy. Weather pictures, and certain communications experiments, require a high degree of pointing accuracy to be effective.

Another objective is to photograph the entire Earth's disk and to take narrow-angle, high-resolution pictures to study the utility of future photos from gravity gradient satellites at synchronous altitudes.

The two-camera system consists of one low resolution camera for photographing the Earth's disk (about 10 miles at picture center) and the other to take high resolution photos of selected areas (one-half mile at picture center). Both cameras will take 800-line photos.

Meteorological pictures from the two cameras can be stored on a single, four-channel 18-pound tape recorder, or sent directly to NASA tracking stations at Mojave, Cal., or Rosman, N.C.

The wide angle camera will take a picture every 10 minutes. The narrow angle camera will take a picture every five minutes. Only one camera will be programmed to operate sequentially in order to get high and low resolution pictures along the orbital track.

The nine-pound wide angle camera has a 12mm lens while the 10-pound narrow camera has a 200mm lens.

These two, one-inch advanced vidicon cameras were previously tested on Nimbus and ESSA weather satellites.

The two cameras have the following general characteristics:

Wide-Angle Camera

Field of view	66 degrees
Ground resolution	Approx. 10 miles per scan line
Lens	12 mm focal length
Aperture	T/1.5, T/5.6, and T/11
Shutter	Focal-plane, double-blade
Picture size	0.44" x 0.44"

Prepare, expose, and readout cycle	39.5 seconds
Resolution (vert.and horiz.)	Approximately 800 lines
Aspect ratio	1:1
Vertical sweep periods	6.5 seconds
Vertical retrace time	250 milliseconds
Horizontal blanking and retrace	375 microseconds per line
Horizontal sweep rate	7.5 milliseconds per line (133.3 cps)
Prepare cycle	26 seconds
Exposure time	40 milliseconds
Readout time	6.25 seconds
Horizontal lines per frame	833 (non-interlaced)

Narrow-Angle Camera

Field of view	4.4 degrees
Ground resolution	Approx. .5 miles per scan line
Lens	200 mm focal length
Aperture	T/4.0, T/8, and T/16
Shutter	Focal-plane, double-blade
Picture size	0.44" x 0.44"
Prepare, expose, and readout cycle	39.5 seconds
Resolution (vert. and horiz.)	Approximately 800 lines
Aspect ratio	1:1
Vertical sweep periods	6.5 seconds

Vertical retrace time	250 milliseconds
Horizontal blanking and retrace	375 microseconds per line
Horizontal sweep rate	7.5 milliseconds per line (133.3 cps)
Prepare cycle	26 seconds
Exposure time	40 milliseconds
Readout time	6.25 seconds
Horizontal lines per frame	833 (non-interlaced)

SCIENTIFIC EXPERIMENTS

Primary scientific experiment carried by ATS-A is an Environmental Measurements Experiment (EME), which consists of eight separate experiments.

Four of the experiments (particle telescope, electron spectrometer, solar cell damage and thermal coatings) were evaluated on ATS-I. The four new experiments are the omnidirectional detector, VLF detectors, cosmic radio noise and electric field measurements.

The EME experiments are designed to measure the orbital environment of the ATS-A spacecraft.

Scientific data obtained by the lower, 6,900 mile orbit of ATS-A, will be compared with satellites at synchronous altitude.

The high-energy electron flux in the outer radiation belt region fluctuates radically because of magnetic disturbances that change its shape, intensity and energy distributions of the electron content.

The high-energy proton flux falls off rapidly with the increasing radial distance and magnetic latitude in this region.

Electrons are lost rapidly from the slot region (between two Van Allen Belts) following any natural or artificial injection of these particles. This loss may be caused by the resonant interaction of electromagnetic waves with the trapped electrons.

Included in the EME package will be a solar cell radiation damage experiment to measure the voltage and current characteristics of solar cells.

Different types of cells (silicon, cadmium sulphide, etc.) will be included.

The surface of the cells will be thermally coated for measuring the absorptivity-to-emissivity ratios of the various coatings. The eight experiments in the EME package include:

Omnidirectional proton-electron counters, Dr. Carl E. McIlwain, University of California, San Diego:

Three scintillation-photomultiplier counters are employed in this experiment; two to measure protons of energy greater than 12.0 Mev and electrons of energy greater than 0.5 Mev, and one to measure protons of energy greater than 20.0 Mev and electrons of energy greater than 1.0 Mev.

Electron magnetic deflection spectrometer, Dr. John R. Winckler, University of Minnesota, Minneapolis:

A magnetic-deflection spectrometer will measure the electron flux in the energy intervals 45 kev to 150 kev, 150 kev to 500 kev, and 500 kev to 1.0 Mev.

Multi-element particle telescope, Dr. Walter L. Brown, Bell Telephone Laboratory, Holmdel, N.J.:

A silicon-junction particle telescope detector will measure electrons, protons and alpha particle spectra in the following energy ranges:

Electrons	0.4 Mev to 12. Mev	2 ranges
Protons	0.7 Mev to 100 Mev	6 ranges
Alphas	1.8 Mev to 85 Mev	5 ranges

VLF Whistler mode detector, Dr. Walter L. Brown, Bell Telephone Laboratory:

Will measure the whistler noise power in eight narrow frequency bands from 5 kc to 45 kc, using two ferrite rod antennas with axes 90 degrees to each other.

Cosmic Radio Noise, Dr. Robert G. Stone, NASA Goddard Space Flight Center, Greenbelt, Md.:

This experiment measures cosmic radio noise in seven frequency bands from 250 Kc to 2.5 Mc, using the 123 ft. gravity gradient booms as antennas and a Ryle-Vonberg radiometer.

Solar cell radiation damage, Dr. Raymond C. Waddel, Goddard Space Flight Center:

Will measure the I-V curves of 30 selected cells having different dopants and cover slides of different type, including the cells used on the ATS solar array.

Thermal coating, Jack J. Triolo, Goddard Space Flight Center:

Will measure the absorptivity-to-emissivity ratio of nine selected surfaces (four spacecraft surfaces) and compare them to a standard surface (stacked razor blades).

Electric field, Dr. Thomas Aggson, Goddard Space Flight Center:

Will measure the differences in potential existing in the plasma surrounding the ATS-A spacecraft using the gravity gradient booms as Langmuir probes, and a log pico-ammeter.

THE SPACECRAFT

The ATS-A spacecraft is a cylindrically-shaped, light-weight structure with a large adaptable volume for mounting various types of experiments.

It is six feet long, five feet wide and weighs 815 pounds. In orbit, the gravity gradient booms fully extended, will measure 252 feet from the tip of one boom to the tip of the boom on the opposite side of the spacecraft.

Primary spacecraft structure consists of a corrugated thrust tube with the adapter attachment provisions at the aft end. Annular shelves extend outward from each end of the thrust tube. Between these shelves and attached longitudinally along the thrust tube are radial stiffeners.

The spacecraft has a cylindrically shaped center compartment with solar panels extending from both ends. The central compartment is divided into two sections by the thrust tube. Both compartments are utilized for component and experimental mounting.

Subliming Solid Jet System

ATS-A will be the first spacecraft to use a subliming jet system for turning a satellite over in orbit.

The satellite will have two jet systems, one on each side of the spacecraft. Thrust will be tangent to the spacecraft skin.

Because of its very small thrust, one quarter of one gram, one of the jets will fire for about an hour to turn the spacecraft completely over.

When inversion is complete, the jet on the other side will fire for an equal time to stop spacecraft motion.

A solid ammonia salt is used as a propellant in this jet system. The propellant looks like camphor or moth balls.

When heated, this salt turns slowly to gas at low pressure. Gas is ducted through a tiny rocket nozzle to produce thrust.

The jet thrust is controlled without moving mechanical parts by a freeze-plug valve.

This method uses a fine screen placed across the gas flow path. The screen normally is cooled by a space-radiator mirror placed in thermal contact with it.

The cooling freezes and resolidifies some of the gas passing through the screen forming a solid barrier which stops further gas flow in a few minutes.

When thrust is desired, the screen is heated by an electric coil in contact with it. Heat vaporizes the solid barrier on the screen allowing gas to flow which produces thrust.

The subliming jet system contains enough propellant for at least 10 complete spacecraft inversions.

Power Subsystem

This subsystem consists of an upper and a lower solar array and two nickel-cadmium batteries. Initially, it supplies about 185 watts of power. This is expected to drop no lower than 125 watts even after three years in orbit, despite the degradation caused by radiation on the solar cells. Most non-peak electrical loads can be sustained by this lower power level.

Each of the solar arrays contains 11,000 solar cells to give the spacecraft a total of 22,000 solar cells to power the spacecraft while in sunlight. These are negative-on-positive (N/P) cells which are protected against much of the space radiation damage by fused silica covers measuring 30 thousandths of an inch thick.

Each of the two batteries contains 22 cell units which provide a total storage capability of 12 ampere-hours. This is sufficient to operate the spacecraft when it is eclipsed from the Sun or when transient peak loads are required.

The two solar arrays and two batteries are divided into separate power subsystems which can be paralleled into one unit on command. Each main solar array directly powers spacecraft systems and maintains the voltage between about 25 and 33 volts. The upper limit is maintained by a voltage limiter and the lower by a battery discharge control circuit.

All experiment payloads and major electrical units are powered by 24-volt regulators which automatically disconnect the payloads from the spacecraft if they draw more than the prescribed current.

A few high current transient loads, such as the spacecraft spin-up system and the apogee motor squibs, are not regulated in this manner. These units are automatically disconnected after firing to insure against short circuit. All of these systems can be reset by the VHF command system.

Command and Telemetry Subsystems

The command and telemetry subsystems will provide ground control of the spacecraft as well as send experiment and basic "housekeeping" data to Earth.

All spacecraft command sequences are initiated at Goddard and transmitted to ATS-Athru one of three ground stations (Rosman, N.C., Mojave, Cal., and Toowoomba, Australia) for transmission to the spacecraft.

The command subsystems on the spacecraft consists of two duplicate receivers and two Goddard FSK decoders. Command signals generated at a ground station are addressed to one of the command decoders but are received simultaneously by both command receivers. The addressed decoder automatically locks onto the receiver with the best signal and stores the command signal.

For verification, the telemetry subsystem repeats the command for the ground station. After verification, the spacecraft is made to execute the command signal by an execute tone sent from the ground station involved. Normal telemetry signals can be checked to verify that the spacecraft has properly executed the command.

Eight command & telemetry whip antennas are affixed to the top outside edge of the spacecraft.

The telemetry system has four two-watt VHF transmitters which operate in redundant pairs on different frequencies and two standard Goddard encoders which can operate in the pulse code modulation (PCM) or the pulse amplitude modulation (PAM) mode. Each encoder has 64 main and 96 sub-channels.

Two of these transmitters are used solely for telemetering data from the spacecraft's Environmental Measurement Experiment package. The EME has its own pulse frequency modulation (PFM) encoder.

The two remaining transmitters, operating with the telemetry subsystem encoders, are used to telemeter "housekeeping" data in both "real time" and delayed time. "Real time" data, which uses six or eight channels of an encoder in the PAM mode, includes information on the apogee motor firing, the nitrogen spinup, and the hydrogen peroxide orientation system operations.

It also includes information from the phase shifter wave forms from the microwave electronically de-spun antenna, and outputs from the Sun (psi) sensor which measures the spin rate and solar aspect angle of the spacecraft.

The remainder of the "housekeeping" data, for which there is no "real time" requirement, uses the PCM encoder mode. In this mode, the encoder samples all 64 of the main channels in three seconds and all the sub-channels in three minutes.

ATS GROUND STATIONS & TRACKING

Command sequences are initiated at Goddard and transmitted to one of the three existing ATS ground stations for ultimate transmission to the spacecraft.

Of the three ATS ground stations, two are located at tracking stations of the world-wide Space Tracking and Data Acquisition Network (STADAN) operated by Goddard. The primary ATS ground station is at the Rosman STADAN facility which has an 85-foot dish antenna. The other is at the Mojave STADAN facility which has a 40-foot parabolic antenna.

The third ATS ground station is a transportable unit at Cooby Creek near Toowoomba, Australia. This station is equipped with a 40-foot parabolic antenna. The antenna system employs a cryogenic low-noise, high-gain amplifier, including a combination of MASER and parametric amplifiers. Both amplifiers are operated in the same refrigerator at an actual temperature of minus 453 degrees F for the MASER and minus 430 degrees F for the parametric amplifier.

The performance of both the MASER and the parametric amplifiers will be compared in communications tests. Remote selection of either the MASER or the parametric amplifier is possible.

In addition to command equipment, these stations have Super High Frequency (SHF) and Very High Frequency (VHF) communications equipment as well as improved range-and-range-rate (R&RR) equipment for tracking purposes.

The R&RR equipment at the ATS ground stations was designed to send and receive signals through the SHF or microwave transponder on the ATS-A. The high power and broad bandwidth of this transponder provides an R&RR signal with a high signal-to-noise ratio. As a result, range of the ATS-A can be determined with a resolution of about five feet in range and approximately 1/3 inch per second in range rate.

Range is a measure of distance from a fixed ground point to the moving spacecraft, and range-rate is the rate of change of this distance from the point.

ATS-A also will be tracked by the world-wide STADAN stations at launch and during the early phases of powered flight. In addition the STADAN will receive telemetry data from the environmental measurement experiment on board the spacecraft.

Participating Stations

In addition to the ATS ground stations, several foreign ground stations will participate in the ATS missions. For the ATS-A mission, however, the only participating station is located at Kashima, near Tokyo, Japan. This facility, operated by Japan's Radio Research Laboratory of the Ministry of Posts and Telecommunication, has a 99-foot parabolic antenna. It is equipped with SHF communications equipment and the same improved range-and-range-rate equipment used for tracking at the ATS ground stations.

ATS-A FACT SHEET

Spacecraft

Cylindrical, six feet long and five feet wide weighing 815 pounds. Spacecraft measures 252 feet in orbit with gravity gradient rods fully extended.

Experiments:

Gravity Gradient:

Compare actual performance with a mathematical model and to establish the design parameters for gravity gradient stabilization systems for synchronous altitudes.

Communications
(Microwave):

Evaluate simultaneous transmission of voice, television, telegraph and digital data to several ground station.

Meteorological:

Evaluate feasibility of using gravity gradient stabilization for meteorological satellites by measuring the perturbations induced by camera systems and a tape recorder. To obtain large Earth coverage and high resolution cloud cover pictures from two advanced vidicon cameras for research purposes.

Scientific:

Environmental Measurements Package consisting of eight experiments to evaluate radiation damage, thermal effects, erosion and energy particle type, density, energy and directivity and magnetic fields.

Albedo
(Department of
Defense):

These are optical and electromagnetic pulse experiments. Their purpose is to obtain background data on the Earth's albedo and electromagnetic radiation in space.

Orbital Elements:

Orbit:

Circular, 6,905 miles

Period:

6 hours 23 minutes

Inclination: 29 degrees

Velocity: 10,680 miles per hour

Power Supply: 22,000 negative on positive (n-on-p)
radiation-resistant silicon solar cells.

Tracking Stations:

Orbit: Seventeen stations in NASA's Space
Tracking and Data Acquisition Network
(STADAN)

Command: Rosman, N.C., Mojave, Cal., and Toowoomba,
Australia.

ATS-I RESULTS

ATS-I was successfully launched from Cape Kennedy, Dec. 6, 1966. The satellite is still operating and is in synchronous orbit over the Christmas Islands in the Pacific.

All test objectives from ATS-I have been met. Engineers and scientists will continue to refine the data being sent from the spacecraft to further spacecraft technology, and improve communications and meteorology.

The latest orbital elements are:

Apogee: 22,234 miles

Perigee: 22,224 miles

Inclination: 0.21 degrees

Drift rate: 0.9 degrees per day, west

Eccentricity: .000202

EXPERIMENTS

Microwave Communications (SHF)

Formal SHF Communications began Dec. 20, and were scheduled for about 13 hours daily.

Most of the experiments have been with television (black & white and color).

Good quality color television pictures have been received at the three ATS ground stations and the Japanese station.

Many of the SHF tests have been conducted in the multiple access mode which means that all of the stations can participate simultaneously.

In the wide band mode, good quality meteorological pictures continue to be received from the spin scan camera system.

Very High Frequency (VHF) Communications

ATS-I was the first satellite which permitted two way voice communications (VHF) between aircraft and the ground.

Increased air travel plus higher performance jet aircraft make this experiment especially appealing over oceanic and sparsely populated areas.

Although this experiment did not formally begin until March 10, the first two-way voice conversation with an airplane in flight was accomplished Dec. 19.

Since the initial test, several more have been conducted with airplanes, including regularly scheduled passenger flights.

Voice tests were conducted between Goddard and airplanes over the Southwest Pacific ocean, along the west coast of the U.S. and over the Gulf of Mexico.

While these early voice communications were good, the quality has improved with new antenna systems. The initial tests were conducted with standard off-the-shelf antennas and associated electronic equipment.

Spin Scan Cloud Camera

ATS-I provided meteorologists with their first look at the world's weather from a synchronous altitude so they could watch the birth and death of storms.

Good quality pictures of 39 per cent of the Earth continue to be received from the Spin Scan Cloud Camera about seven hours daily.

These pictures are taken at 20-minute intervals. Several sets have shown cloud movement from dawn until dusk. The cameras have also photographed the Moon.

A movie was made from photographs taken Jan. 7 and 8, which shows the following items very vividly to meteorologists:

- Diverging air in a high pressure area over Baja, Calif.;
- The motion of the jet stream in the southern hemisphere;
- The advance of a frontal system in the northern hemisphere;
- The easterly tradewind belt on both sides of the Equator;
- The change in cloud formations due to convection and thunderstorm activity;

An extensive area of convection activities apparently tied to the ocean surface, possibly a warm water area south of the Equator. The upper clouds drift rapidly northward deep into the northern hemisphere;

Changes in shape of Sun glint on the ocean to provide a possible measure of sea state.

Weather Facsimile Experiment (WEFAX)

Good quality weather facsimile pictures, maps and charts are being received by several of the simple Automatic Picture Transmission (APT) U.S. stations, and one in Toronto, Canada.

This experiment is being scheduled about two hours daily.

Environment Measurements Experiment (EME)

All seven of the scientific experiments on the ATS-I spacecraft are working and sending data back to Earth.

The seven experiments include:

1. Omnidirectional detector
2. Particle telescope
3. Electron spectrometer
4. Solar cell damage
5. Thermal coatings
6. Ion detectors
7. Magnetometer

Preliminary results are available on two of these experiments, solar cell damage and thermal coatings.

Both experimenters, Dr. Raymond C. Waddel (solar cell damage) and Jack J. Triolo (thermal coatings), are from the Goddard Space Flight Center.

The ATS-I thermal coatings experiment was designed to determine the stability of thermal control coatings in the space environment. Samples of the coatings are thermally isolated from the satellite and thermistor networks measure the sample temperature.

From this temperature, the solar absorptance over thermal emittance (a/e) ratio is calculated; this a/e ratio is the coating property that is used in spacecraft thermal design. By monitoring the sample temperature, the change in a/e as a function of time in space can be determined.

The results of the first 65 days in space indicated that six of the seven coatings changed from 10 to 100 per cent of their original values.

This information will determine the validity of laboratory degradation studies and will be used to improve the thermal design of future satellites.

The object of the solar cell radiation damage experiment was to determine the merits of various kinds of solar cells, the power generators widely used on spacecraft, in resisting the damaging effects of the electrons and protons trapped in the Earth's magnetic field or emitted by the Sun.

The 30 solar cells in this experiment were all made of silicon, but had different dopants and shields. The condition of each shield was observed at various times by successfully connecting one of eight different load resistors to it and telemetering the voltage developed to a ground station.

First data obtained by this experiment came three days after launching when ATS-I was in a preliminary elliptical orbit awaiting the apogee motor firing which would kick the spacecraft into synchronous orbit.

During this elliptical orbit, ATS-I passed through trapped radiation three times. It appears damage to these cells was due almost entirely to these three passages.

One of the cells used in this experiment is a modern n-on-p (negative on positive) silicon solar cell, of base resistivity 10 ohm-cm. It is shielded by 30 mills of corning 7940 fused silica.

This cell is believed to be undamaged and still develops maximum power of 28.6 mv.

A similar cell, which had no shield, has deteriorated and produces only 17.2 mv of power.

In another unshielded n-on-p cell of only one ohm-cm base resistivity, which is similar to the cells used on earlier spacecraft, the power has dropped to 12.1 mv.

A p-on-n, one ohm-cm cell, which was used on the very early spacecraft like Vanguard I, has suffered severe radiation damage. It develops only 5.9 mv.

The ATS-I solar cell radiation damage experiment has clearly confirmed the advances man has made in solar cell technology.

Further results from this experiment will show the amount of solar cell radiation damage at synchronous altitudes.

ATLAS/AGENA LAUNCH VEHICLE

An Atlas/Agena D launch vehicle is used to boost the ATS-A spacecraft into its 6900-mile-high circular orbit. The Atlas provides the ascent power to place the upper-stage Agena and its ATS payload into a coast ellipse at a velocity of about 21,000 mph.

The Agena engine's first burn, occurring between six and ten minutes after launch, puts Agena/ATS on a transfer orbit. After engine shutdown, the vehicle coasts along this transfer orbit toward the 6900-mile-high apogee.

During the coast period, the Agena guidance system aligns the thrust axis properly so that, on second burn, the orbit will be circularized at the high point of the transfer orbit. Second burn occurs (almost two hours after liftoff) over Burma or South China. After second burn, the spacecraft is re-oriented by the Agena and separated.

Atlas Booster Phase

The Atlas/Agena/ATS-A lifts off from launch complex 12 at Cape Kennedy. Two inches of vehicle rise activates the on-board autopilot programmer. This autopilot subsequently controls all Atlas sequences including selected gimbaling of the engines. The two Atlas booster engines are gimbaled in pitch, yaw and roll while the two vernier engines are gimbaled only in roll to provide stability during the booster engine phase.

Two seconds after launch, a 13-second Atlas roll program begins to align the vehicle along the azimuth of the flight trajectory. When the roll program is terminated, the pitch program begins.

Some 130 seconds after launch, the booster engines are shut down (BECO), the booster section is jettisoned and the single Atlas sustainer engine continues the booster flight alone.

Sustainer engine cutoff (SECO) occurs approximately 290 seconds after liftoff. A propellant-depletion switch will provide a controlled engine shutdown should the vehicle run out of propellants before engine shutdown is accomplished by the guidance command.

Immediately after SECO, the Agena standard sequence timer is started. This time varies according to the actual flight performance and inputs from the Mod. III ground guidance system. Vehicle stability is maintained by gimbaling the vernier engines in pitch, yaw and roll.

Separation

Simultaneously with VECO, the horizon sensor fairings on the Agena are ejected and the Agena gyros are uncaged. Slightly more than two seconds later, Agena is cut free of the Atlas and the retrorockets on the booster adapter section are fired to retard the Atlas and the booster adapter. This allows the Agena to draw free as its aft section rolls out of the booster adapter on guide rails. The Agena then coasts for almost a minute.

Agena Phase

Some 370 seconds after liftoff, the Agena engine control is armed, first burn is initiated, and the velocity meter is enabled. In slightly more than three seconds, the Agena engine reaches a steady state thrust. About nine seconds later, the ATS spacecraft shroud is ejected.

Agena's first engine burn lasts for approximately 208 seconds. The on-board velocity meter sends the shutdown signal when the vehicle has reached the desired velocity and nominal 115 mile altitude. Agena, carrying the now unshrouded ATS spacecraft, will coast to a nominal 6900 mile apogee where the second burn will circularize the orbit. During this coast, the velocity-to-be-gained number for the second burn is loaded into the counting register.

Two seconds before second-burn ignition, the Agena velocity meter is enabled again. Second burn starts almost 2 hours after liftoff. Twenty-seven seconds of engine thrust will attain the desired circular orbit.

After second shutdown, Agena again coasts during preparations for spacecraft separation. The Agena vehicle yaws to the right (looking forward) to align the spacecraft properly. This takes about 27 seconds. Then the spacecraft separation squibs are fired. This occurs off the west coast of Australia.

Immediately after separation, the Agena is further yawed to a tail-forward position and stabilized. Some 700 seconds later, a solid propellant retrorocket on board the Agena is fired. This, plus a second retrorocket fired at T plus 12,030 seconds, eliminates any possibility of interference with the ATS spacecraft on succeeding orbits.

COUNTDOWN MILESTONES

<u>Event</u>	<u>T minus time (minutes)</u>
Start countdown	425
Autopilot system tests	190
Atlas battery load checks	185
Start UDMH tanking	155
Finish UDMH tanking	135
Remove gantry	125
Start IRFNA tanking	90
Finish IRFNA tanking	65
<u>Built-in-hold of 55 minutes</u> (to meet launch window requirements)	60
Start LOX tanking	40
Autopilot final test	30
Final systems check	25
Telemetry final warmup	25
<u>Built-in-hold of 5 minutes</u> (to meet launch window requirements)	7
Telemetry to internal	3:30
Destruct armed	1:45
Secure LOX tanking	2:10
Atlas to internal power	1:40
Hold for automatic sequencer	18 seconds
Ignition	4 seconds
Atlas engines to full thrust	2 seconds
Liftoff	0

-more-

The following sequence of events is representative of a typical ATS-A flight. Actual times of these events will vary with the time and day of launch and vehicle performance. That is, on-board systems monitor the position and velocity of the vehicle during the actual flight and, on the basis of final trajectory objectives, the guidance system will command any necessary flight corrections.

SEQUENCE OF EVENTS

<u>Time From Liftoff (sec)</u>	<u>Event</u>
0.0	Liftoff
129.0	Atlas Booster Engine Cutoff (BECO)
132.0	Booster Jettison
290.5	Atlas Sustainer Engine Cutoff (SECO)
295.0	Start Agena Timer
310.3	Atlas Vernier Engine Cutoff (VECO)
312.5	Atlas-Agena Separation
372.4	Agena First Burn Start
379.0	Jettison
577.28	First Burn Shutdown
7117.39	Agena Second Burn
7141.15	Second Agena Engine Cutoff
7241.0	Agena Spacecraft Separation
7244.0	Vehicle Rotates Nose Right
7277.0	Stop Yaw Program

Launch times for ATS-A are determined largely by the solar power requirements of the spacecraft. The following launch "windows" are subject to final changes to accommodate tracking facilities on the day of launch.

-more-

	<u>Open (EST)</u>	<u>Close (EST)</u>
April 4	10:02 P.M.	12:02 A.M. (April 5)
April 5	10:00 P.M.	12:00 Midnite
April 10	9:49 P.M.	11:49 P.M.
April 15	9:39 P.M.	11:39 P.M.

ATLAS AGENA STATISTICS

The Atlas-Agena D for the ATS-A mission has the following general characteristics:

Height (including shroud): 109 feet

Weight: 278,889

Diameter (maximum): 10 feet

Lift-off thrust: 388,000 pounds

First stage:

Height: 67 feet

Weight: 261,219

Diameter (maximum): 10 feet

Thrust: 388,002 pounds

Propellants: Combination of RP-1 fuel
(11,563 gallons) and Li-
quid Oxygen (18,626 gal.)

Propulsion: Two booster engines, one
sustainer and two vernier
engines

Guidance: Auto-pilot and ground based
General Electric radio
command

Second Stage: Height: 42 feet (includes 19 foot shroud)
 Weight: 16,855 pounds
 Diameter: 5 feet
 Thrust: 16,000 pounds at altitude

Propellants: Combination of 570 gallons
 of Unsymmetrical Dimethyl Hy-
 drazine (UDMH) and 740 gallons
 of inhibited red fuming nitric
 acid (IRFNA).

Propulsion: One regeneratively cooled
 engine

Guidance: Agena IRP (inertial reference
 package), horizon scanners and
 onboard flight programmer.

THE ATS-A TEAM

The following key officials are responsible for the
Applications Technology Satellite-A Program:

NASA Headquarters

Dr. Homer E. Newell, Associate Administrator for Space
Science and Applications

Leonard Jaffe, Director, Space Applications Programs
Office

Joseph R. Burke, ATS Program Manager

Vincent L. Johnson, Director, Launch Vehicle and Propul-
sion Programs

J. B. Mahon, Agena Program Manager

Goddard Space Flight Center

Dr. John F. Clark, Director

Robert J. Darcey, ATS Project Manager

Robert H. Pickard, ATS Spacecraft Manager

Lewis Research Center

Dr. Abe Silverstein, Director

H. Warren Mohr, Agena Project Manager

Edward F. Baehr, Manager, Atlas Project

Kennedy Space Center

Robert H. Gray, Assistant Director for Unmanned Launch Operations

Major Contractors

Space Systems Division
Hughes Aircraft Co.
Culver City, Cal.

ATS-A Spacecraft

Missile & Space Division
General Electric co.
Valley Forge, Pa.

Gravity Gradient Stabilization
System

General Dynamics/Astronautics
San Diego, Cal.

Atlas booster

Lockheed Missile & Space Corp.
Sunnyvale, Cal.

Agena D vehicle

Major Subcontractors

Airborne Instrument Lab., Deer Park, N.Y., development of MASER and parametric amplifier for ATS Transportable Ground Station.

deHavilland Aircraft of Canada, Ltd., Toronto, Canada, development of the primary and damper gravity gradient rods.

General Dynamics/Electronics, San Diego, Cal., fabrication of range and range-rate equipment at all three ATS ground stations.

General Electric Co., Communications Products Division, Lynchburg, Va., built baseband multiplex microwave communications equipment for all three ATS ground stations.

Gulton Industries, Inc., Metuchen, N.J., fabrication of EME solar cell experiment.

Lockheed Missiles and Space Co., Sunnyvale, Cal., development of subliming solid jet system.

Marshall Labs., Torrance, Cal., fabrication of EME magnetometer and suprathreshold ion detector.

North American Aviation, Inc., Columbus, Ohio, built 40-foot antenna for ATS Transportable Ground Station.

Philco, Western Division Lab., Palo Alto, Cal., integrated antenna feed system at Mojave ATS ground station.

Rantec Corp., Palo Alto, Cal., integrated antenna feed system at Rosman ATS ground station.

Raytheon Co., Equipment Division, Norwood, Mass., built FM and SSB communications transmitters for all three ATS ground stations.

RCA Victor, Montreal, Canada, built communications receivers for all three ATS ground stations.

Radio Corporation of America, Princeton, N.J., development of advanced vidicon cameras (meteorological) and tape recorder.

Sylvania Electronics Systems, Waltham, Mass., integration, test and installation of ATS Transportable Ground Station at Australia.

Westinghouse Electric Corp., Defense and Space Center Systems Division, Baltimore, integration, test and installation of ATS ground stations at Rosman, N.C. and Mojave, Cal. Integration of the Environmental Measurement Experiment (EME) and fabrication of the EME Thermal Coatings unit. Design and fabrication of Communications Test and Evaluation Console (CTEC) and Master Control Console at all three ground stations.